THE

PATHOLOGICAL SIGNIFICANCE

OF

NEMATODE HÆMATOZOA.

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The present contribution to be considered as a continuation of previous observations.

SOME interest having been taken in a report which I had the honor of submitting to the Government, in 1872, on the existence of innumerable immature nematode entozoa in the blood of persons laboring under certain diseases, I trust that the following additional contribution towards the extension of our knowledge in the same direction will not be unacceptable. A few of the clinical observations made since the issue of that report have been incorporated in the reprint of it which appeared in the *Indian Annals of Medical Science*;† others have been made subsequent to these and have not appeared in any journal, and the announce-

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* Forming an Appendix to the Tenth Annual Report of the Sanitary Commissioner with the Government of India.

† No. XXXII, January 1874, pages 504 to 519.

ment that the blood of pariah dogs is, not infrequently, somewhat similarly affected will, I believe, as regards India, be quite new; as will also the description of the pathological conditions frequently co-existing with this state in these animals—a pathological condition which I have not yet been able to find recorded with regard to the dogs of India or of any other country.

A summary of the previous observations.

It will, perhaps, be as well to recapitulate in a few words the leading facts referred to in the report in its original form, so that readers of this paper who may not have seen the former will be the better able to form an estimate of the bearing of the observations now recorded on the facts and inferences then adduced.

These were to the effect that the blood of persons suffering from the diseased condition known as chyluria contained minute nematode worms (evidently the embryos of some hitherto undetected nematode, provisionally named, for the sake of convenient reference, *Filaria sanguinis hominis*), averaging $\frac{1}{75}$th of an inch in length and having a transverse diameter of about $\frac{1}{3\,5\,0\,0}$th of an inch; not differing materially from the young of many other nematodes, except by the fact of their being enclosed in delicate, translucent sheaths, within which they can be observed to elongate and contract themselves so as to be able, within the space of a moment, either to occupy the entire length of the enveloping tube, or only one-half of it or even less than that: That I had obtained these entozoa in the blood of four persons, in the urine of about

A brief description of the 'Filaria sanguinis hominis.'

fifteen, and in the profuse coagulable discharge from the lachrymal or meibomian ducts of one; all the persons being affected with chyluria except one, whose history was unknown and could not be ascertained: That one of the cases had been under observation for more than two years, during which period the young filaria had undergone no appreciable change, at least in so far as could be inferred from the fact that those which I had detected in his urine in March 1870 differed in no way from those found in his blood as well as in the urine in October 1872.*

Morbid conditions associated with its existence in the blood.

It was further stated in the report that one of the persons, a European woman, suffering from chyluria, in whose blood I had frequently detected hæmatozoa, had died at the Medical College Hospital, and that Dr. McConnell, the Professor of Pathology, had made a very careful *post-mortem* examination, without the slightest evidence of any parent to the parasites being obtained, although in the kidneys and supra-renal capsules, which Dr. McConnell had kindly forwarded to me, numerous examples of the young were found without difficulty. The following passage describes the state of these organs: "No morbid changes could be detected as having taken place in either the tubular or cortical tissue of the kidneys, but in every fragment, no matter

Post-mortem appearances in a person affected.

* It may here be stated that young filariæ remained in the vascular system of this person without undergoing any appreciable morphological changes until April 1873. He was at this period admitted into the Presidency General Hospital, under Dr. Coull Mackenzie, suffering from diarrhœa, which, however, soon passed off. He then became subject to frequently recurring attacks of fever, and died rather unexpectedly in a state of high delirium. Unfortunately no *post-mortem* examination could be held.

from what part of the kidneys removed, numerous microscopic filariæ were invariably obtained, if the tissue had been properly teased, precisely analogous to those which had been detected in the blood and in the urine during life. Teased fragments of the suprarenal capsules yielded similar specimens. On slitting open any portion of the renal artery, from its entrance into the kidney as far inwards as I was able to follow its ramifications, and gently scraping its inner surface, numerous hæmatozoa could always be obtained. The renal vein, when similarly examined, also yielded specimens of the filariæ, but they did not seem to be so numerous in it."

The inferences which were made as to the connection of the parasites with certain diseases.

From these observations it was inferred that the disease commonly known as chyluria, was generally, if not always, due, directly or indirectly, to the presence of this entozoon in the system, and that the condition of the urine could only be looked upon as one of the symptoms of the existence of this parasite, although it appeared to be the most characteristic symptom with which we were acquainted; and lastly, the opinion was expressed that some of the hitherto inexplicable phenomena by which certain tropical diseases are characterised might eventually be traced to the same or to an allied origin—such diseases being implied as would naturally suggest themselves to professional readers wherein some impediment to the flow of the nutritive fluids of the body appeared to have occurred, as is commonly believed to be the case in various elephantoid

conditions; especially such of them as were characterised by the exudation of a more or less chyle-like fluid from different parts of the body, and which have commonly been attributed to various obstructing causes, such as the pressure of tumours, idiopathic diseases of nerves and vessels—doubtless in many instances quite correctly so. "Nevertheless," it was maintained, "cases occurring in warm countries, or in persons who had formerly resided in them, appear to indicate that the disease is, probably, not dependent on such mechanical or pathological causes as these."

Since these remarks were published, several cases of such a nature have come to my notice, and all have been, when diligently enquired into, confirmatory of them in the highest degree.

Hæmatozoa in dogs and other animals.

Before referring to these, however, it will be more convenient to study the pathological conditions associated with the existence of young nematode worms in the blood of the pariah dogs referred to in the opening paragraph, in order to ascertain whether some more satisfactory clue can be obtained by means of comparative data of this kind as to the pathological significance of the human hæmatozoon here referred to, than can be derived from pure inference, or from the observations concerning nematode hæmatozoa generally, hitherto put on record. A rapid retrospect of such of these observations as appear to be more or less closely associated with the subject may be of interest to such of my readers as have not made it a matter of particular study.

The canine hæmatozoa discovered in France,

In a brief *résumé* of the more generally known hæmatozoa among lower animals which was given in the former paper, reference was made to the discovery made by MM. Grube and Delafond, more than twenty years ago, of microscopic nematode worms in the blood of dogs in France.* They were about $\frac{1}{100}$th of an inch in length with a transverse diameter somewhat less than that of a red blood-corpuscle. Out of 480 dogs examined, from four to five per cent. were found to be thus affected; but on one occasion only were MM. Grube and Delafond able, by *post-mortem* examination, to detect parasites in the bodies of the animals, visible to the naked eye, which could be looked upon as parents to the microscopic worms in the blood. On the occasion referred to, however, they were able to satisfy themselves on this point by the discovery of six *white*, filiform worms (four males and two females) in the *right* ventricle of one of the animals. These were from five to seven inches in length and from $\frac{1}{25}$th to $\frac{1}{16}$th of an inch in width; the anatomical details could be clearly made out, as also the stages of the development of the ova in the ovaries and of the embryos in the oviducts, the embryos being considered identical with the microscopic worms in the blood.

and in China, Japan, &c.

In the same paper attention was also drawn to the observations recorded concerning the worms found, frequently and in considerable numbers, in the *right* cavities of the hearts

* *Comptes Rendus*, tome XXXIV, 1852, pp. 11–14.

of dogs in China and elsewhere. These are commonly looked upon as identical with the mature examples found by MM. Grube and Delafond, and we have now the high authority of Dr. Cobbold for considering those of China at least, as identical with the *Filaria immitis* of Leidy.*

The "cruel thread worm" of Leidy.

On referring to a description of the American parasites by Professor Leidy, which, by the way, in the first record we have of them, were named by him *Filaria canis cordis*,† we find it stated (in addition to the various anatomical details common to the Filaridæ, among others that the caudal extremity of the male is provided with 'a row of five tubercles and a narrow ala upon each side') that the length of the female is 10 inches, and the breadth $\frac{1}{2}$ a line; length of male 5 inches, and the breadth $\frac{1}{4}$ of a line. The Professor continues—"Mr. Joseph Jones lately presented to me two specimens of the heart of a dog, in the *right* ventricle of one of which there were five of the filariæ just described. In the other specimen the right auricle and ventricle and the pulmonary artery in its ramification through the lungs are literally stuffed with filariæ." A portion of the blood of this dog contains a great number of the young of the filariæ. Both these animals are referred to as being very lean—one is described as being "so thin as to resemble a skeleton, and it was impossible to benefit his condition with the most liberal supply of food."‡

* *Lancet*, vol. I, 1873, p. 462.
† Proc., Acad., Nat. Science, Philadelphia, vol. V, 1850-51, pp. 17-18.
‡ *Op. Cit.*, vol. VIII, 1856, p. 55.

Mr. Leidy does not give the minute anatomy of these filariæ, nor does Schneider (whose description generally coincides with that of Leidy, and accurately so with reference to the caudal extremity of the male *); but the omission as to the microscopical characters of the worm has been so exhaustively supplied by Dr. Welch, Assistant-Professor of Pathology at Netley,† and by Professor Cobbold,‡ that there can be no possible excuse for future workers in this field of research to confound totally distinct entozoa.

It should be noted that the mature worms discovered in France, China, and America, are described as being found in the cavities of the *right* side of the heart and vessels of the *venous* circulation.

Leiserung's discovery of 'Strongyloid' worms in the venous circulation of dogs.

Dr. Cobbold has also recently called the attention of English readers to a paper in Virchow's *Archiv* for 1865, by Professor Leiserung, on the existence of minute, though mature, parasites in the *venous* blood of certain parts of the circulation of dogs—males, females, and embryos being found. The female worms (presumably larger than the male) did not exceed $\frac{1}{12}$th of an inch in length and the free embryos averaged $\frac{1''}{108}$th. Dr. Cobbold considers the parasites to belong to the strongyloid group of worms, and has given other particulars concerning them in his lately published excellent manual "On the Internal Parasites of our Domesticated Animals,"—a work which, I regret, is

* Monographie der Nematoden, 1866, p. 87.
† Monthly Microscopical Journal, October 1873, pp. 157—170.
‡ Proc., Zoological Society, London, November 1873, pp. 738—741.

not at present in my possession, as I am thus obliged to fall back upon the few hasty notes which were made whilst perusing the volume a few weeks ago for the particulars just given of Leiserung's observations.

The foregoing paragraphs contain the leading features of all the information which I have been able to glean with reference to the existence of hæmatozoa in dogs: I could find no allusion whatever to any such condition being manifested by dogs in India.

Discovery of hæmatozoa in pariah dogs in India.

Whilst making a microscopic examination of some gland tissue from the mesentery of a pariah dog (last July), I observed that the sanguineous fluid squeezed out of the preparation on the slide contained numerous minute nematode worms in a state of great activity, and presenting at first sight a marked resemblance, both as to the character of their movements and their size, to the hæmatozoon referred to above as existing in human blood. I had for a long time been desirous of obtaining living specimens of a canine hæmatozoon so as to be able to institute a comparison between this kind and those found in man, although I had not entertained any very sanguine hope of being able by this means alone to pronounce definitely as to the identity or otherwise of the two parasites, for it has long been known that the embryos of many filariæ of widely differing size and habitat present no appreciable difference either of size or form:

instances being known of the young of even a totally distinct group of nematodes being nevertheless so like as to be miscroscopically undistinguishable the one from the other.

This canine hæmatozoon and the 'Filaria sanguinis hominis' compared.

It was, however, very evident that should any anatomical or other marked discrepancy be observable in parasites subject to the same influences, there could be no difficulty in coming to a very positive opinion on the matter. With reference to the particular hæmatozoa under consideration, the anatomical disparities are so unmistakable that I have not the slightest hesitation in

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DESCRIPTION OF PLATE I.

Human and Canine Hæmatozoa.

Fig. 1. Nematode hæmatozoon *(Filaria sanguinis hominis)* found in man. It is represented as slightly contracted at either end—corresponding portions of the sheath being empty ... ... × 300

„ 2. Nematode hæmatozoon as found in pariah dogs. No trace of a sheath visible ... ... × 300

„ 3. Mature *Filaria sanguinolenta;* found in the walls of the aorta and œsophagus of pariah dogs in India, male ... ... Natural size.

„ 4. Ditto ditto, female ... ... Natural size.

„ 5. Three ova of ditto ditto in various stages of development ... ... × 300

„ 6. Two ova of ditto ditto, ruptured by pressure on covering-glass—an embryo is seen to escape from each ... × 300

„ 7. A portion of the aorta of a dog slit open. A mature parasite is seen to be partially projected into the channel of the vessel from each of the tumours. One of the tumours has been cut open ... Slightly enlarged.

„ 8. A sketch of the thoracic cavity of a pariah dog whose blood contained hæmatozoa. Tumours are seen along the course of the aorta and œsophagus—in one place stretching the pneumogastric nerve. The course of the thoracic duct along the aorta is indicated by dotted lines.

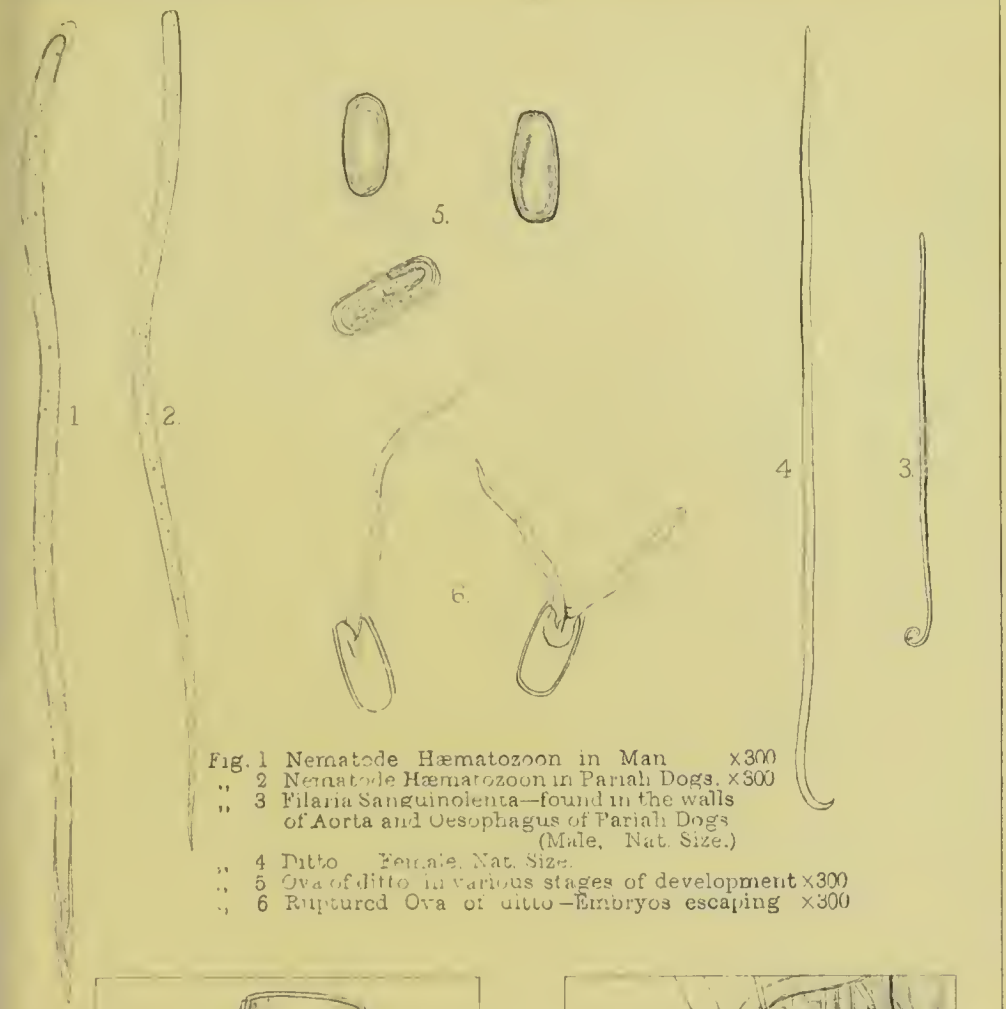

Fig. 1 Nematode Hæmatozoon in Man ×300
" 2 Nematode Hæmatozoon in Pariah Dogs. ×300
" 3 Filaria Sanguinolenta—found in the walls of Aorta and Oesophagus of Pariah Dogs (Male, Nat. Size.)
" 4 Ditto Female. Nat. Size.
" 5 Ova of ditto in various stages of development ×300
" 6 Ruptured Ova of ditto—Embryos escaping ×300

Fig. 7 Section of Aorta of a Dog with Filaria-tumours on its walls; slightly enlarged.

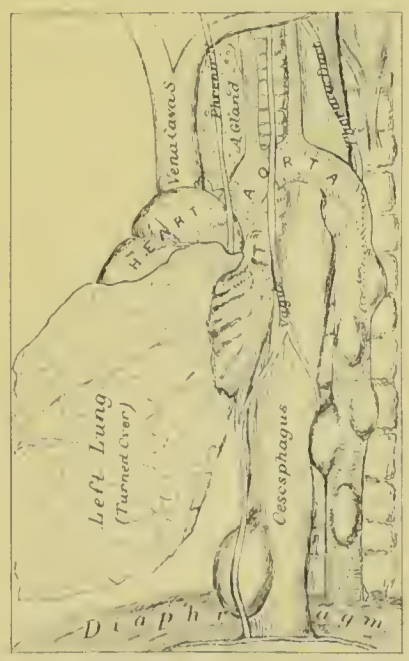

Fig. 8 Sketch of the Thoracic cavity of a Dog, whose blood contained innumerable Hæmatozoa.

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HUMAN AND CANINE HÆMATOZOA.

pronouncing them to be totally distinct parasites. Dr. Douglas Cunningham, who has repeatedly and most carefully examined both kinds in the living state, is equally satisfied on this point.

The anatomical differences observable.

For the sake of comparison, figures have been introduced of these human and canine hæmatozoa (Plate I, Figs. 1, 2), from which it will be perceived that they correspond very closely as to size : the average measurements of the latter may be stated as about $\frac{1}{90}$th of an inch from end to end, and about $\frac{1}{450}$th at the widest part,the average dimensions being slightly smaller than those yielded by the human parasite. The relative proportion of the breadth to the length in the canine variety is about 1 to 50, the tail occupying about $\frac{1}{5}$th or $\frac{1}{6}$th of the total length—the relative proportions also differing somewhat from those of the young *Filaria sanguinis hominis*.* The measurements and proportions, however, vary to some extent according as the parasite is measured in the extended or the contracted condition.

This canine hæmatozoon not provided with an enveloping capsule.

I can detect no indication whatever of this canine hæmatozoon being enclosed within any enveloping tube, such as the structureless, hyaline, tubular sac, enclosing the human parasite,

* On one occasion I detected a specimen in the blood of a dog yielding much lower measurements, *viz.*, $\frac{1}{175}$ of an inch in length by $\frac{1}{5000}$ of an inch at the widest part, the breadth being to the length as 1 to 34. In this respect also the canine embryo parasite differs from the *Filaria sanguinis hominis*, as the proportion between the breadth and the length in the smaller specimens instead of diminishing, as in the canine variety, increases considerably—the smallest specimen which was measured of the human variety having been $\frac{1}{7000}$ of an inch at the widest part, and $\frac{1}{125}$ of an inch in length ; the width being to the length as 1 to 56, whereas in the larger specimens it was found to be as 1 to 45.

and within which the latter parasite can be observed to contract and elongate itself—no portion of it being structurally adherent to the enclosing sac. Whether this tube is the old cuticular covering of the embryo, which parasites of this kind are known to cast off during the process of development, and which, under this altered condition, becomes more permanent (for it can hardly be supposed that the blood is the natural habitat of this parasite, seeing that no very evident developmental changes take place), or whether it be merely the dilated, attenuated covering with which the embryo was originally invested, I am unable to decide.† As the cyst invests the parasite very closely laterally, and is, to some extent at least, elastic, there is frequently some difficulty in distinguishing it from the body of the worm proper, especially when, as is usually the case, the fluid in which it is found contains molecular matter which obscures the minute structure of the parasite; or when death occurs, as is commonly the case, whilst the worm is fully extended, and it thus occupies the whole length of the tube. During life, however, when the movements are not too rapid, and the field is cleared of molecular matter, the saccule may, as far as my own experience goes,—and I have examined some thousands of specimens,—always be distinguished if the microscope be good and the illumination properly adjusted.

† Since this was written, I have observed that Schneider has suggested a somewhat similar explanation with reference to the capsule which appears to envelope the young of *Ichthyonema globiceps*: "Embryonen von einer Hülle umgeben, ob dieselbe durch Häutung order durch Erweiterung der Eihülle entsteht, ist ungewiss" —Monographie der Nematoden, s. 175.

On one occasion it seemed as though I had succeeded in detecting such a cyst in the canine hæmatozoon —a lifeless specimen immersed in fluid, but subsequently it was found that the appearance observed was due to the specimen having been torn across a short distance from the caudal end; the granular substance of the worm had escaped at the part, thus leaving a hyaline tube (containing, however, a few oil molecules) formed by the investing membrane proper of the worm: the detached fragment was subsequently found on the same slide.

Deceptive appearances frequently produced by osmic acid fumes.

When specimens of the blood of the dog infested with these parasites are spread out in very thin layers upon glass slides and subjected to the fumes of osmic acid, in the manner recommended on a former occasion in connection with the *Filaria sanguinis hominis*, a deceptive appearance is frequently produced by the contortions which the worms may undergo during the process of "setting" of the serum. A double outline results highly suggestive of an enveloping cyst. The osmic acid appears to act on the serum before causing the

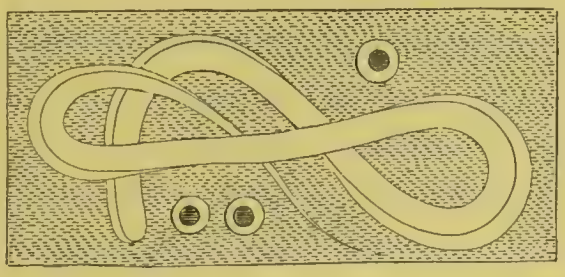

Fig. I. × 600.

The Canine Hæmatozoon and three red blood-corpuscles fixed in serum by osmic acid. The clear space alongside the parasite is owing to the removal of the film of serum by contraction of the worm.

death of the Filaria, so that the latter contracting after the serum has become partially solidified produces a clear space, which may be evident at either end or alongside the worm, as may be observed in the accompanying woodcut.

It will, however, be sufficiently clear that this appearance is produced by the *ante-mortem* contractions of the parasite, from the simple fact that the spaces are nearly always along the convexities of the outline of the worm. Had the spaces been due to the folds of a cyst, they would have been found along the concavities.

The utility of examining the blood of dogs affected with hæmatozoa.

Notwithstanding these minute anatomical discrepancies, which are of importance in considering the natural history of the two parasites, their resemblance is sufficiently striking, that I would strongly advise those who are interested in the human hæmatozoon, and have not had the opportunity of examining it for themselves, but are anxious to obtain a more definite conception of the *Filaria sanguinis hominis* than can be obtained from written descriptions and drawings, to make arrangements with some of the low-caste persons employed in destroying sickly, pariah dogs, to collect a few ounces of the blood of these animals.

Method of examination recommended.

The fluid should be examined at first by means of a low power, such as a $\frac{2}{3}$rd of an inch objective—the layer of fluid between the slide and the covering glass being as thin as possible. Should any worm-like body manifest activity on

the slide, the $\frac{2}{3}$rd objective should be replaced by a good $\frac{1}{4}$th or still better a $\frac{1}{8}$th of an inch immersion object glass. Should, however, this proceedure not prove successful after having tried several dogs, it will be found advisable to get the aorta itself and gently scrape its lining membrane with the edge of a covering glass. Should the dog be affected at all, the probability is that the parasite will be found here. It must not be expected that the blood will present any peculiarity to the naked eye, even though every ounce may contain thousands of embryo-worms.

Character of the movements of the parasites.

With regard to the movements of the canine variety, it may be stated that they are strikingly like those of the *Filaria sanguinis hominis*, and not materially different from the movements of filaria-embryos generally. I have, however, frequently observed the canine worms attached, at the oral extremity, to the under-surface of the covering glass, or to the slide, and swinging in all directions from this fixed point—the oral extremity being blunted whilst in this condition. I have watched them thus attached for more than an hour, but have not observed a similar feature in the movements of the human variety.

Their internal structure.

The internal structure of both is pretty much alike; in neither is there any visible differentiation of the reproductive organs, and only in a very minor degree of the alimentary tract; if anything, the canine parasite is perhaps the more advanced.

Degree of prevalence of this canine hæmatozoon.

With reference to the degree of prevalence of this condition among dogs, it may be stated that of the animals which I have examined in Calcutta with this special object in view, more than a third were found to be affected. I have kept notes of twenty-seven such examinations, and find it recorded that the blood of ten of these dogs was found to be invaded to a greater or less extent by these embryo-worms.

The pathological appearances associated with the existence of these parasites in the blood of pariah dogs.

Before attempting to arrive at any conclusion as to the probable or possible source of these embryos, it will be advisable to describe briefly the pathological conditions which usually accompany their presence. These, as far as may be inferred from very careful dissections of the twenty-seven dogs above referred to, may be described as follow :—

1. The most striking feature is the existence of fibrous-looking tumours, varying from the size of a pea to that of a filbert or walnut, along the walls of the thoracic aorta and œsophagus, both tubes being affected, or only one. (Plate I, fig. 8).

2. Minute nodules in the substance of the walls of the thoracic aorta, from the size of duck shot to that of split peas. They can be felt as tubercles, and usually project somewhat on the outer surface of the vessel; a depression or slight extravasation of blood, corresponding to the nodule, being visible on the inner surface

of the aorta (Plate II, figs. 9, 10), and frequently a slight abrasion of the lining membrane.

3. A pitted or sacculated appearance of various portions of the interior of the thoracic aorta with thinning of its walls at some parts; the lining membrane roughened at the spots affected; the roughening, however, is not of an atheromatous character, but due to the membrane being thrown into delicate rugæ, as if from contraction of the middle and outer coat.

4. Enlargement and softening of some glandular body adjoining the vessels at the base of the heart.

Within the above four headings is comprehended everything abnormal that I have been able to detect, which seemed to imply any connection with the state of the blood under consideration.

The nature of the larger tumours referred to under 1.

(1).—As regards the first point referred to, the tumours manifest a somewhat firm, fibrous texture, and when cut into are found to contain one to six or more mature nematode worms, of a pinkish, sanguinolent tint, and varying in size from one inch to three and a half inches in length. These on closer examination prove to be the male and female of the same parasite: the male worm being from one to two inches long, and $\frac{1}{50}$th to $\frac{1}{40}$th of an inch in diameter at the widest part; and the female from two to three and a half inches long with a transverse measurement of from $\frac{1}{30}$th to $\frac{1}{25}$th of an inch. (Plate I, figs. 3, 4.)

The mature parasites which these tumours contain—Filaria sanguinolenta.

These parasites correspond more closely to the *Filaria sanguinolenta* (Rudolphi), especially to the description of this species given by Schneider, than to any other nematode with which I am acquainted, although in some respects they differ from the descriptions given of any.

It is, however, with regard to the parts of the body in which these parasites are found that the most marked discrepancy exists, for all writers, as far as I am aware, with the exception of Czernay,* appear to speak of them as confined to the walls of the stomach† of the dog

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* Bulletin de la Soc. Imp. des Naturalistes de Moscow, Tome xxxviii.

† With regard to the statement made by writers generally, that the *Filaria sanguinolenta* is principally found in the walls of the stomach, it may be remarked that on no occasion have I observed any such occurrence in India. The only parasite with which I am acquainted, located in this situation, is one which I am unable to refer to any described species. It is lodged in a tumour, generally of the size of a small horse chestnut, continuous with the walls of the stomach. The tumour presents a hard fibrous texture, and communicates with the interior of the stomach by a small orifice into which a portion of the lining membrane of this viscus appears to be reflected. When cut into two, or more, worms will be seen coiled in a hollow in the centre of the tumour.

The parasite most generally found in the stomach of dogs in India—an *Echinorhynchus*.

These worms vary in length from $\frac{3}{4}$ths of an inch to an inch, with an average diameter of about $\frac{1}{20}$th of an inch. When placed under a microscope, the anterior half of the body is seen to be covered with sharp spines; and rows of tænia-like hooklets (Fig. II, 5) encircle the dome-shaped 'head.' The 'head,' or rather proboscis, is frequently so completely retracted as to be altogether invisible (Fig. II, 2). When protruded, two prominent 'lips' of complex conformation project beyond the globular 'head,' disposed laterally, each being surmounted by a papilla permeated by a duct—not a nerve, as particles, may occasionally be observed to escape from these two papillæ (Fig. II, 3).

The upper portion of the body is covered with chitinous spines, arranged like plates of armour, each little plate terminating in two or three sharp spikes (Fig. II, 6), the points being directed backwards. The tail of the male is slightly pointed, has a well-marked transverse slit on its ventral aspect, through which two spicules of unequal length occasionally emerge, and on either side four granular processes (papillæ ?) are seen to diverge from the middle line, with one papilla-like ray extending to the tip of the tail (Fig II, 4). There is no bursa, properly so called, nor are there distinct alæ, but in a state of contraction the orifice, through which the spicules escape, is pulled up, so as to give rise to a funnel-shaped cavity. There are numerous transverse rows of minute hooklets with the points directed forwards, extending from the caudal orifice upwards, about as far as the upper end of the

or wolf. This writer, however, has drawn attention to the fact that they may also be found in the walls

longer spicule when retracted; their number and size diminishing as they extend upwards (Fig. II, 7).

I have not been able to make out the existence of either oral or anal apertures, nor been able to isolate any structure analogous to an alimentary canal, and conclude, therefore, that the parasite is an *Echinorhynchus*—possibly a hitherto undescribed species. All the specimens which I have examined have been males.

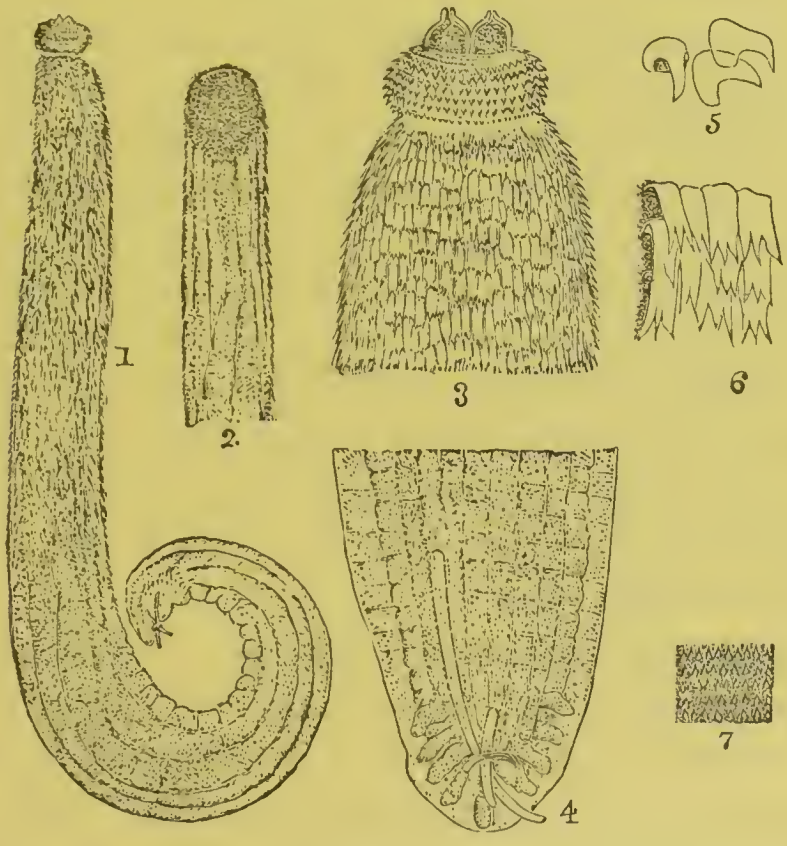


Fig. II. ECHINORHYNCHUS FROM THE WALLS OF THE STOMACH OF A PARIAH DOG.

No. 1.	The parasite entire: proboscis exserted (Male) ...	×	6
„ 2.	Anterior portion of parasite; proboscis retracted...	×	6
„ 3.	Ditto ditto ditto exserted ...	×	25
„ 4.	Posterior portion of parasite	×	25
„ 5.	Hooks surrounding proboscis	×	260
„ 6.	Prickly plates covering the anterior portion of the body	×	260
„ 7.	Small hooks arranged in rows on posterior portion of the body	×	260

of the œsophagus. Notwithstanding the somewhat extended reference to the works of systematic writers on these and allied subjects, which, through the courtesy of Mr. Wood-Mason, Curator of the Indian Museum, I have been able to make, I can find no mention of their lodging themselves in the walls of the blood vessels.

Nature of the smaller tumours referred to under heading 2.

(2).—As far as the aorta is concerned, the condition referred to under the second heading is the one of most frequent occurrence; and as in this condition the parasite may be obtained in various stages of advancement, it will be better to describe the smaller tumours and their contents before referring more minutely to the mature *Filaria*, especially as this will give an opportunity of studying the growth of the parasite from a very early period till it reaches maturity. Specimens in almost every stage of development may sometimes be found lodged in the walls of a single aorta.

Although the tumours enveloping the young are much smaller than those in which the mature worms are usually lodged, the lesions, as far as the tissues of the walls of the artery are concerned, appear to be of a more serious nature, for frequently the walls of the vessel are very fragile at various places and there is a considerable roughening of its inner wall.

Towards the earlier stages of the attack of this parasite, a cursory examination of either the inner or the outer surface of the aorta may not convey to the observer the impression that there is anything unusual

present, but on closer inspection slight indications of roughening or of dryness of the inner surface will be evident, as if indicative of commencing atheromatous changes. There may be either a small depression at the part or a slight elevation, and when the artery is drawn between the finger and thumb, a little tubercle, varying in size from that of a millet-seed to that of a pea, may be more or less clearly evident. (Plate II, fig. 10.) Frequently also, on careful examination, a thin serpentine line may be detected lying immediately beneath the inner coat of the artery. (Plate II, fig. 9.)

The partially matured parasite.

When one of the smaller tubercles is cut into and the tissues carefully dissected under a low magnifying power, a curled, hair-like object will generally be observed (Plate II, figs. 9, 10); this, when examined under a higher power, will be found to be an immature worm, but manifesting considerable evidence of organisation and in a state of great activity. They may be so small as not to exceed $\frac{1}{10}$th of an inch in length or more than $\frac{1}{150}$th transversely at the widest part. Some yield even smaller measurements than this.

The mouth and alimentary tube.

At this stage of development no reproductive organs can be discerned. The oral end terminates in two pointed papillæ, dorsal and ventral, which can be brought closely together, so as to form a sort of 'borer,' by which means, possibly, the parasites bore their way through the tissues. (Plate II, figs. 11 to 13.) The alimentary canal is well differentiated, the œsophagus occupying above $\frac{1}{3}$rd of the

entire length of the worm: a well-marked sphincter-like constriction exists a short distance below the mouth, probably indicating the junction of the pharynx with the œsophagus. The intestinal canal terminates on the convex surface, a short distance from the end of the tail; the latter is somewhat blunt, and is tipped with a trefoil-like object (glandular?), communicating with a tube and apparently containing a transparent fluid. (Plate II, fig. 13.)

DESCRIPTION OF PLATE II,

The development of Filaria Sanguinolenta in the walls of the Aorta of Dogs.

Fig. 9. Longitudinal section of the aorta of a dog. Three, more or less distinctly marked, patches are seen on its inner surface; the lowest, having been dissected under a low power, displays a hair-like parasite ... ... Natural size

„ 10. A portion of the aorta of a dog with parasite-tumours firmly adherent to it. Towards the middle one of the tumours is seen to have been cut into, and a minute worm is distinguishable ... ... Natural size.

„ 11. One of the parasites removed from a tumour. The pharynx and œsophagus occupy more than two-thirds of the entire length of the alimentary canal. Reproductive organs not distinguishable ... ... × 12

„ 12. Ditto, ditto, undergoing the process of casting its skin; the old cuticle is seen to have become torn across ... × 12

„ 13. As Fig. 11. Shortly previous to the period of moulting. The continuity of the, shortly to be discarded, cuticle, with the termination of the alimentary canal is very evident ... ... × 100

„ 14. Ditto in a more advanced stage of development, the sex having become distinguishable. A young female worm. The vagina is seen to terminate a short distance above the junction of the œsophagus with the intestine, then to divide into two uterine tubes which are seen, in the lower portion of the figure, to be continuous with the ovarian tubules ... ... × 10

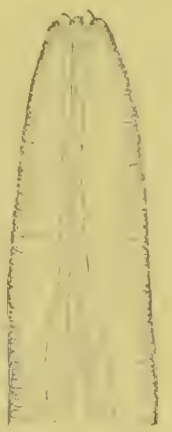
„ 15. A young male worm, nearly mature. The spermatic tube is seen to commence cæcally towards the anterior portion of the parasite and to wind along the intestinal canal until the caudal extremity is reached. The two spicules have also become developed ... ... × 10

Fig. 9.....Nat. Size
Interior of Aorta.

Fig. 10.....Nat. Size
Exterior of Aorta.

Fig. 11..... x12
Immature Worm, removed from a small tumour in the walls of the Aorta.

Fig. 12..... x12
As Fig. 11, but undergoing the process of Moulting.



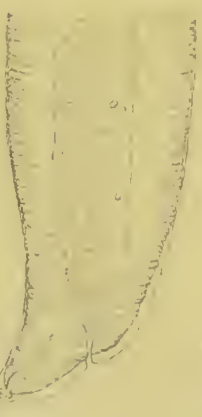


Fig. 13. 100
As Fig. 11 - more highly magnified.

Fig. 14 x10
Young female Worm. Reproductive organs differentiated, but Ova not formed.

Fig. 15..... x10
Young male Worm. The spermatic tube and spicules distinctly visible.

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The process of 'moulting.'

During this period of its growth the worm undergoes a moulting process—casting off its skin entirely. (Plate II, fig. 12.) When the cuticle has become somewhat separated from the body of the worm shortly before the 'moulting' actually occurs, the continuation of the old cuticle with the lining of the oral and anal orifices is very evident, as also the fact that it forms a coating to the tri-lobed gland-like object at the caudal extremity.

The advent of reproductive organs.

This process of moulting appears to be repeated several times, and each time some slight modification occurs in the appearance of the worm, especially at both ends; it also increases in size. The prominent papillæ with which the mouth is furnished gradually disappear, and, by the time that the worm has acquired a length of about $\frac{3}{4}$ths of an inch, reproductive organs can be distinctly made out and the sex identified. No ova, however, can be detected in the genital tube of the female at this stage (Plate II, Fig. 14), and the spicula in the male are not developed until after the spermatic tube and the sheath of the retractor muscles of the larger spicule. The œsophagus is proportionally much shorter, and the tri-lobed object at the caudal extremity almost completely disappears.

The migration of the newly matured parasites into adjoining tumours.

The worm gradually acquires a more decidedly pinkish hue, and instead of occupying a little tumour alone, as it did when very small, it appears to make

its way into some adjoining tumour. Other worms also migrate to this, so that one tumour may be common to several parasites. It should, however, be noted that they do not all occupy a single cavity, but each tumour is tunnelled in various directions, so there is frequently some difficulty in pulling out the parasites without tearing or otherwise injuring them.

Sometimes observed to protrude a portion of their bodies into the channel of the aorta.

Sometimes they may be seen to have crept outside the tumour, lying between it and the serous covering investing the artery, or a parasite may be seen emerging through a minute orifice communicating between the tumour and the interior of the aorta and swinging itself across the lumen of the artery (Plate I, Fig. 7). I have observed the channel of the aorta almost entirely blocked up after death by a clot which had formed around a worm in this position.

The smallest measurements of matured specimens.

When the parasites have acquired a length of about $\frac{3}{4}$ths of an inch to an inch, and a transverse diameter of about $\frac{1}{40}$th, they will be found to have acquired nearly all, if not all, the microscopical characters distinctive of the *Filaria sanguinolenta;* and, as already mentioned, every stage in the development may be represented by examples of the parasite in the tissues of a single aorta—in the thoracic portion of it: I have never observed the abdominal aorta to be affected in this manner, nor have I observed the parasite in this condition in any tissue beyond the limit of the thoracic cavity.

The sacculated condition of the aorta referred to under heading 3.

(3).—With regard to the third heading into which the pathological features of this phase of parasitism has been divided, namely, the sacculated external and scarred internal appearance of the aorta, it may be observed that these changes appear to have been produced by the development of the filaria as above described, by their subsequent migration to adjoining tumours and various tissues; and probably, also, by the death and subsequent softening and absorption of some of the parasites—an assumption supported by the fact that, frequently, on pricking an affected spot of this kind, on the walls of the aorta nothing is found except an accumulation of soft pultaceous substance filled with fatty molecules and plates of cholesterin.

A gland penetrated by the mature parasite.

(4).—Sometimes the three foregoing classes of morbid appearances may be found to occur in a single animal; indeed, the only occasion on which I observed the condition described under the fourth heading, now to be referred to, was also associated to some extent with the other three. The blood of a dog was found to be affected to a slight degree with hæmatozoa, and the aorta was scarred and nodulated; but no mature parasites could be detected anywhere, except in a tumour in the walls of the œsophagus. On careful examination of the thoracic viscera, however, a gland, or what seemed to be one, was observed to have become enlarged and softened near the origin of the left carotid artery. (Plate I, Fig. 8.) This tissue on being cut into, was

found to have degenerated into a pultaceous mass composed of oil molecules and plates of cholesterin; but coiled in the midst of this softened material were five mature specimens of the *Filaria sanguinolenta*—male and female.

This observation shows that the mature parasites, at all events, may be found in other tissues than those of the thoracic aorta and œsophagus.

Description of the mature parasite—Filaria sanguinolenta.

It is not deemed necessary to enter into any very minute description of the anatomical characters of the matured *Filaria sanguinolenta* as found in dogs in India, as these do not differ very materially from those of various other filariæ which have been described by various writers from time to time.

The figures in plate III will, I trust, be sufficient to give a tolerably clear idea of the general appearance and internal anatomy of the mature entozoon when examined under the microscope; but it should be remarked that, in some instances, a higher power has been used to make out the structures than the extent of amplification stated opposite each figure would imply. To have drawn the figures to scale, as observed under higher powers, would have added greatly to the difficulties of reproducing them without adding materially to their value.

The oral and caudal extremities of the male worm.

Fig. 16 represents the anterior portion of the mature parasite; the mouth with its six, indistinctly marked, 'lips;' the chitinous pharynx, and the upper portion of its muscular œsophagus: whilst the adjoining fig.

(17) gives the appearance of the mouth and entrance to the pharynx as seen from the front. Fig. 18 represents the ventral aspect of the tail of the male with its two dissimilar spicules and four pre-anal papillæ—characters which, when taken in conjunction with the arrangement of the muscular tissues of the body, form the distinctive features of the genus *Filaria* (Schneider). There are also two post-anal papillæ, placed transversely to the body of the worm; so that in all there are twelve papillæ, terminating on the inner surface of the alæ which form the boat-shaped cavity on the ventral aspect of the coiled tail of the male.

The reproductive organs of the male worm.

The mode of formation of this cavity will be more readily comprehended by a reference to fig. 19, which represents a dissection of the tail of the male as seen from the side (magnified 30 diameters). It will be observed that the cuticular and muscular sheaths of the worm have been slit up, and the two retractor muscles (*e e*) continuous with the sheath (*f*) of the larger spiculum, are seen to arise from either side of the left lateral band. (The well-marked curvature of the tail in the male, so common among the *Filaridæ*, is, in this case certainly, due in a great measure to the strength and elasticity of the larger spiculum; when this is extracted the curvature loses its firmness.) The alimentary tube (*a*) is seen to run parallel with the spermatic tube (*b c*), a sphincter-like constriction occurring on the course of the latter, separating the '*vas deferens*' (*b*) from the 'testis' (*c*). The 'testis' consists of a tube extending upwards in a

serpentine manner until the junction of the upper with the middle third of the body and terminating cæcally as shown at (*d*). Fig. 20 represents the molecular and cellular contents of this tube.

The oral cavity and alimentary canal in the female worm.

The head of the female worm (Fig. 21 *a*) does not differ from the head of the male, except that it is somewhat larger. The specimen delineated had been immersed in spirit, which had separated the chitinous cuticle from the other tissues; so that the continuation of the former with the pharynx has been made very evident, the pharyngeal

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DESCRIPTION OF PLATE III.

Fig. 16. Anterior extremity of a mature *Filaria sanguinolenta*, showing the lateral aspect of the mouth, the pharynx and upper portion of the œsophagus ... ... × 60

„ 17. The mouth as seen from the front, with its six minute 'lips' and chitinous pharynx ... ... × 80

„ 18. Caudal extremity of the male. Ventral aspect. Two spicules are seen of unequal length, with eight pre-anal and four post-anal papillæ ... . × 25

„ 19. A dissection of the posterior extremity of the male. The cuticular and muscular coverings have been divided and the various organs exposed :—*a* Intestinal tube :—*b Vas deferens* separated by a sphincter-like constriction from the *testis* (*c*) ; the cæcal extremity of this tubule is represented separately at *d* : *e e* Retractor muscles of the longer spicule (*f*) ... ... × 30

„ 20. Cellular bodies pressed out of the spermatic tube .. × 500

„ 21. Three portions of a mature female *Filaria sanguinolenta* :—

a. Anterior portion, the outline of the mouth altered through separation of the cuticle by the action of spirit.

b. Termination of genital tube ; the vagina, twisted on itself, is seen lying alongside the intestinal canal immediately below the junction of the latter with the œsophagus. It is distended with ova and divides into the two uterine tubes.

c. Caudal extremity : The two uterine tubes with cellular contents, are observed to terminate abruptly in minute tubules (the ovarian) which form coils around the lower portion of the alimentary canal ... × 20

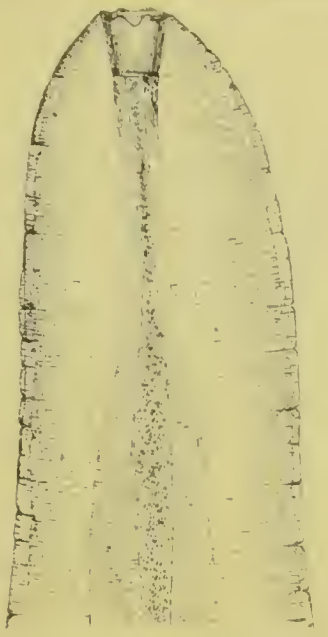


Fig. 16..... ×60

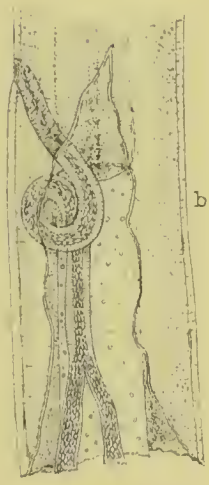
Anterior extremity of a mature specimen.

Fig. 17..... ×80

Front aspect of mouth

Fig. 18.....×25

Posterior extremity of male. Ventral aspect.



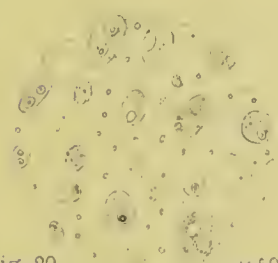


Fig. 20..... .....×500

Contents of Spermatic Tube.

Fig. 19..... 30

Dissection of posterior extremity of male.

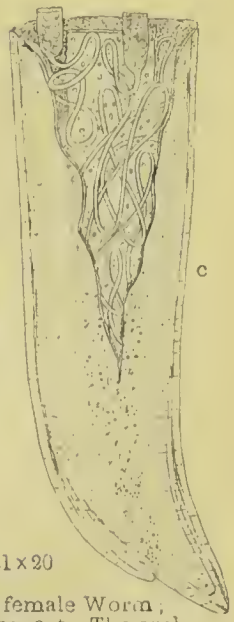


Fig. 21×20

Mature female Worm; lateral aspect. The oral extremity altered by immersion in spirit.

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membrane being merely a reflection inwards of the skin; a similar reflection takes place at the other end of the alimentary canal. The course and texture of the œsophagus and intestinal canal are the same as in the male, and do not differ from such structures in the *Filaridæ* generally.

The reproductive organs of the female worm.

The vagina (Fig. 21 *b*) terminates about $\frac{1}{6}$th of an inch below the oral extremity, generally a little above the junction of the œsophagus with the intestine, as represented in the plate. It is a well-developed muscular tube, composed of longitudinal and transverse fibres, and the channel is occupied by a row of ova lying two or three abreast. It is about $\frac{1}{4}$th of an inch in length, is curved upon itself about the middle and divides into the two uterine tubes delineated in the figure (21 *b*). These tubes are also filled with ova, each ovum containing a more or less clearly differentiated embryo, especially towards the vaginal end; but in no part of the genital tract are free embryos to be found. On tracing the course of the uterine tubes by means of a low power until within about a quarter or half an inch of the caudal extremity (Fig. 21 *c*), they are found to terminate in still smaller tubules (the ovarian); and these, after forming numerous coils around and alongside the intestinal tube, terminate abruptly in a cæcal manner, retaining pretty much the same diameter throughout their entire course.

The caudal extremity of the female Filaria.

The caudal extremity (Fig. 21*c*) of the female is not so complicated as that of the male; it is very slightly pointed, and

at its extremity something suggestive of the remnant of a gland, or of the site of *exit* of the water-vascular system, may frequently be discerned: in the male also a similar appearance may often be detected.

The ova.

The ova in the earlier stages are oval, but as the development of the contained embryo advances, the firm, though thin, 'shell' becomes more elongated and the ends of the ovum more blunt (Plate 1, Fig. 5). The ova are about $\frac{1}{750}$th of an inch in length and about $\frac{1}{1600}$th in width. When a ripe ovum is crushed beneath the covering glass a well-developed embryo escapes, which, however, does not manifest any activity (Fig. 6).

The liberated embryos.

The embryos when thus deprived of their covering vary somewhat in size, the average dimensions, of the particular specimens measured, were found to be about $\frac{1}{200}$th of an inch from end to end and about $\frac{1}{6000}$th at the widest part—just $\frac{1}{300}$th as broad as long. With reference to these embryos it may be further remarked that the thickish, yellowish fluid in which the mature worms are imbedded may be squeezed through the orifice in the tumour (usually found without difficulty) communicating either with the aorta or the œsophagus, according to its anatomical relations. In this way innumerable ova may be made to pass into either channel, as the fluid is well charged with eggs in all stages of development.

Free embryos not found in the intestinal canal of affected dogs.

I have not, however, observed any free embryos in this fluid, nor could I find any along the whole course of the intestinal

canal in the dogs examined, where the parasites were lodged in tumours in the œsophageal walls, although plenty of ova, apparently unaltered, could be detected throughout the entire gut.* On one occasion only have I observed ova on a slide of blood containing hæmatozoa: this preparation was obtained by scraping the inner surface of the aorta with the edge of a covering glass.

It would, therefore, appear that the ova require some considerable time before the escape of the embryo takes place, certainly a longer period than is sufficient for them to be conveyed the entire length of the intestinal canal.

Attempts to hatch the ova unsuccessful.

I have made numerous attempts at bringing the embryos to maturity: by means of moist earth; by feeding cockroaches with bread soaked in fluid containing ova; by introducing ova into the stomach and peritoneal cavity of frogs, &c., but have not yet succeeded—the ova and their contained embryos being, from a week to a fortnight afterwards, detected in the bodies of the animals without having undergone any apparent change.

Where the true habitat of these embryos may be is as yet unknown. Whether, after a lengthened sojourn in moist earth, or in water, or in the intestinal canal of some creature other than the dog, the embryo escapes and undergoes developmental changes, must be left for future enquiry, as must also the direct proof that the

What is the relation of the embryos in the blood to the embryos in the ova?

* *Dochmius trigonocephalus* is the ordinary nematode entozoon found in the intestines of dogs in India.

microscopic worms in the blood of the pariah dog are the brood of the *Filariæ sanguinolentæ* which may be lodged in the walls of the aorta or œsophagus, or in some other tissue, glandular or connective, about the base of the heart or elsewhere. All that I can say is that all my attempts at finding any other mature nematode in the vascular system of dogs affected with hæmatozoa have proved fruitless, and I have made careful examinations —macroscopic and microscopic—of every tissue and organ of the bodies of several animals, and followed the ramifications of the various arteries and veins in the trunk and in the extremities. On one occasion, no trace of any mature parasite in a hæmatozoa-affected dog could be found, but it is quite possible that the parent may have escaped detection by being lodged in some out-of-the-way tissue in the body, and one worm might contribute many thousands of ova; or the worm, after depositing its ova, may have taken its departure, or have died and become disintegrated. The scarred and sacculated condition of the aorta, already described, which is sometimes observed unassociated with any parasite at the time of the examination, shows that the worm that produced the lesion may altogether disappear.

Moreover, we require to know far more than is at present known concerning the development and parentage of these canine microscopic blood-worms, before anything definite can be stated with reference to their relationship to similar organisms found in the blood of dogs in France, China, Japan, and America.

So far as I am aware, Dr. Spencer Cobbold is the only author who has suggested that the young of the *Filariæ sanguinolentæ* may possibly find their way into the blood*—a suggestion which is the more noteworthy, seeing that, to the best of my knowledge, no observations had been recorded showing that this nematode ever penetrated the arteries.

The blood appears merely to serve as a resting place for escaped embryo worms until transferred to a medium suitable for their development.

Although I have not been able to keep individual dogs affected with this hæmatozoon during any lengthened period, still there can hardly be any doubt but that, as has already been shown with reference to the human hæmatozoon and been previously remarked concerning hæmatozoa in animals generally,† these microscopic worms may exist for a considerable time in the blood (unaltered after having attained a certain, very imperfect stage of development), shewing that they were not in the place or fluid fitted for their growth. Their presence in the blood, it may therefore be presumed, is accidental, or if not exactly accidental, the young brood requires at least to be transferred to some other habitat before undergoing even the most elementary morphological changes.

Probable mode of development of the Filaria sanguinolenta.

When, however, the ova or liberated embryos of the *Filaria sanguinolenta* find their way into a 'host' or other medium suitable for their development during

* Entozoa: an Introduction to the Study of Helminthology, London, 1864, p. 95. Supplement to ditto, p. 63.

† In dogs in France and China; in the frog; and in the crow:—Leuckart: *Op. cit.* p. 102.

the larval stage—a stage in their development carried on, possibly, to the extent of providing the embryo with some kind of oral armature and a differentiated intestinal tube. Having acquired this stage of growth, the further progress of the parasite is probably dependent on its being swallowed by some such animal as the dog, to the mucous lining of whose œsophagus it attaches itself, then penetrating the muscular tissue of this tube and remaining there or working its way still further till it reaches the tissues of the thoracic aorta, or some other place suitable to its growth and development; the various stages of which, when the aorta has been selected, have been described on a previous page.

Are there any morbid phenomena indicative of the presence of this canine hæmatozoon during life?

With reference to the morbid phenomena indicating the presence of these parasites in the vascular system of dogs during life, I have no definite knowledge. Some of the affected animals have been of the most miserable kind, others have appeared to be in the enjoyment of perfect health—facts which appear to me to favour the inference that when actual mischief does take place, the cause may be due to the lesions induced by the migrations of the growing and more or less mature parasite, rather than by the microscopic brood in the blood. It would not surprise me, should it eventually be demonstrated, that the haggard, loathsome appearance presented by a great number of the pariah dogs of every Indian town is, in many instances, primarily due to the injuries inflicted on the vascular and other tissues of the animals by these parasites—a diseased state which

cannot be attributed to age or to want of food, for the associates of these animals, under the same conditions, are perfectly healthy.

Application of the foregoing facts to the pathology of the subject in man.

In applying the lesson in pathology which these observations on animals appear to afford towards the elucidation of the diseased condition associated with nematode hæmatozoa in man, it should be specially borne in mind that the parents of these blood-worms may be very much smaller than the mature entozoa described above, consequently their detection at a *post-mortem* examination may be even much more difficult than is the case with the canine worms.

That this is probably the fact, the experience of an accomplished pathologist, Dr. McConnell, testifies, for, as already mentioned, he could detect no mature parasite in the body of a person whose blood, during life, was known to be contaminated with young *filariæ*.

A second post-mortem examination of a person whose blood contained the Filaria sanguinis hominis.

Since this paper was in type, I have, through the kindness of Dr. McConnell, had the opportunity of examining all the organs of the body of another person whose blood contained innumerable examples of these embryo-worms. The subject was a Native, aged sixteen, who had been brought to the Medical College Hospital in a moribund state. No previous history could be obtained, except that he had suffered from 'fever,' and he did not appear to possess any friends in Calcutta. The youth died within a few

hours after admission, and Dr. McConnell made a *post-mortem* examination of the body on the following morning. No evidence of special disease could be found, but on making a microscopic examination of a clot of blood from the heart he was surprised to find numerous specimens of the *Filaria sanguinis hominis*. He thereupon most kindly came to me, bringing some specimens with him, and invited me to make a minute examination of the body which had been specially set aside for the purpose.

On the following morning, some thirty-six hours after death, I made a careful examination of all the organs *in situ*, but failed to detect any mature parasite. The surface of the entire body was examined to make sure of the absence of such parasites as the Guinea-worm, as far as external marks would be a guide, but nothing was found.

All the organs were preserved in spirit, as were also specimens of the various tissues of the body. I have since examined the heart with its vessels; the lungs; the liver; the spleen; the kidneys, and their excretory ducts; the bladder; the intestines; the brain, &c.; but have not, as yet, been able to detect any mature parasite—the embryo-filariæ, however, were present everywhere in abundance. I regret that the final result of the examination cannot be recorded at present as the press cannot be delayed; but the fact that I have already spent two whole days in making the examination will be sufficient to show that it was more than a cursory one.

The morbid conditions associated with hæmatozoa in man.

What are the salient morbid phenomena associated with the presence of nematode hæmatozoa in man? As far as my experience has hitherto extended, they may be described as diseased conditions referrible to the escape of the nutritive fluids of the body out of their proper channels into some organ or into the cellular tissue, or of obstruction to their flow—the fluid extravasated being chylous, sanguineous, or a combination of the two.

Speaking generally, these morbid conditions may be described as manifesting themselves in two principal forms:—

1. As an exudation or extravasation into some excretory tract—especially the urinary:
2. As an exudation or extravasation into the subcutaneous tissues.

The classes of cases in which the urinary tract only is affected.

1. With reference to the escape of nutritive fluid into the urinary tract, it may be stated that, in addition to the fifteen cases of the diseased state commonly known as 'Chyluria,' described at length in the previous report on this subject, about fifteen more cases of the affection have come under my notice, so that ample opportunities have been afforded for putting the observations then recorded to the test. In these, as in the former cases, *filariæ* were invariably detected, either in the blood, the urine, or in both.* The malady is not so very rare as is commonly supposed; indeed, on one occasion, as

* One of the persons affected in this manner had been a Leper for several years previous to the advent of Chyluria.

many as five fresh cases came under my notice within a single month. Some of these are of special interest, as illustrating peculiarities in the disease which were not evident in the cases previously recorded.

Case of uncomplicated Chyluria—third attack.

For one of the first cases which came under my notice since the publication of the first series of these observations I am indebted to Dr. Charles Macnamara. The patient was a house-keeper, age 52, the mother of six children, of whom two only are living. She informed me that four years previous to her visit to me in 1873, her urine had suddenly become of a milky aspect, but that in the course of a month it regained its normal appearance. Eighteen months subsequent to this the disease returned without any premonitory symptoms being observed. It disappeared as before, but returned as bad as ever. I pricked one of her fingers with a needle and distributed a drop of the blood thus obtained over six slides, in two of which several active hæmatozoa were detected

Case of Chyluria—three attacks in two years.

To Dr. McConnell I am again indebted for opportunities of observing several cases of chyluria. One was a native shopkeeper, who, two years previous to his visit to me, had an attack of the disease, lasting for about six months. The morbid symptoms ceased suddenly, and did not return for four months, but when they did so he was affected for some three months or more. He was unmolested for the next seven months, at the end of which period the disease returned. It will be noted that during two years this person experienced three

attacks of chyluria, suffering from the disease for more than nine months out of the twenty-four.

Case of Chyluria—sixth attack within 2½ years.

A somewhat similar case, but rather more aggravated, was kindly sent to me by Dr. Henry Cayley. The patient was a young man, an East Indian, born and brought up at Madras, and suffering when I saw him from a sixth attack of chylous urine. The first came on in September 1871 after a residence of two years at Coconada. All the attacks had lasted about two months each, so that from the first onset of the disease until now he has suffered for about twelve out of thirty months.

Hæmatozoa were present in the blood of both these cases; as many as two dozen were counted in eight preparations from the finger of the case last cited. The urine also contained the parasite.

Case of Chyluria—first attack.

I do not remember to have met with a patient suffering from an undoubted first attack of the disease until August of the present year—a case which is also of interest owing to the fact that the patient had never slept out of Calcutta, and had not travelled more than about 20 miles beyond it. The man, who had been referred to me by Dr. McConnell, was an East Indian, age 22, a printer. A month previous to the interview he had observed his urine to present a slightly milky aspect, on the second day the milkiness increased, and on the third a slight trace of blood was evident. The only premonitory symptoms had been "a dull, aching pain"

over the lumbar vertebræ, which, however, was not so severe as to keep him from work. The pain had lasted for about three days before the urine became affected, and it seems to have passed off when the milkiness appeared. There was no previous history of the disease in the family, but his mother had suffered from hæmaturia two years ago.

The blood was examined and found to contain numerous examples of the *filariæ*. I did not examine the urine, but Dr. McConnell informs me that he did so and found that *filariæ* were present in it.

The four foregoing cases may be looked upon as fair examples of the disease uncomplicated by any other known morbid condition, and may serve as types of the class in which the urinary tract appears to be the only portion of the economy whose functions are disturbed.

The class of cases in which the sub-cutaneous tissue is affected.

2. There is, however, another class of cases characterised by the exudation of nutritive fluid into the sub-cutaneous tissues, the fluid either accumulating and forming pouches under the skin and subsequently becoming exuded through orifices more or less minute, or retained until artificially evacuated to allay the pain caused by the tension produced on the surrounding tissues—which are generally in a state of hypertrophy. This affection has long been looked upon as intimately related to chyluria, and, as already remarked, I considered it probable that the *Filaria sanguinis hominis*

would before long be found associated with it as well as with chylous urine. This inference I have since shown to be perfectly correct, so that now not only the pathology of these maladies, but the etiology also, is linked together by this parasite being found in the circulation of persons laboring from both classes of diseases. Dr. Fayrer, who, probably, has seen more cases of an elephantoid nature than any one living, has suggested the possibility of such an occurrence in his recently published work; * and Dr. W. J. Palmer, in an essay on some of the common forms of our local skin diseases, has expressed a somewhat similar view.†

The two classes of diseases affecting the same person.

The two classes may, however, be present in the same person, the urinary tract being previously affected in some cases and the sub-cutaneous tissues subsequently; whereas, in other cases, the chylous urine symptoms may not be manifested for years after the advent of the elephantoid.

The first occasion on which the filaria was found associated with the elephantoid condition of the scrotum—Chyluria a subsequent occurrence.

The first occasion on which I was able to satisfy myself on this point was towards the end of 1873, when through the kindness of Dr. Ewart I was able to examine some whey-like urine, highly albuminous, and exhibiting a tendency to coagulate. The patient, a Jew, was suffering from acute pain produced by an inflamed condition of a moderately large scrotal tumour. This tumour had been coming

* Clinical and Pathological Observations in India, London, 1873.
† Indian Medical Gazette, Vol. VIII, 1873.

on for many years, and increased and diminished in bulk at irregular intervals. It was studded with tubercular prominences, soft and yielding to the touch, and when a trocar was introduced several ounces of a sanguineous fluid were withdrawn. This was, however, not found to yield sufficient relief, so that a more formidable operation had subsequently to be resorted to. The urine also contained occasionally a little coagulated blood in addition to the chylous fluid, and *filariæ* were detected in it on the two occasions on which specimens were examined microscopically by me.* The chyluria had only been observed about a fortnight previously.

The second occasion—Chyluria not yet appeared.

The next case, for which I am indebted to Dr. Coull Mackenzie, was that of an East Indian, 35 years of age. Unlike the preceding, the scrotal affection was of short standing, nine months only, and chyluria symp-

* Considerable difficulty was experienced in detecting the *Filaria* in this case. It required fully *five hours* of steady application to the microscope before a single specimen could be found, although they were subsequently found without much difficulty. In the reprint of the former paper on this subject in the 'Indian Annals,' the following remarks with reference to this matter were introduced as a foot-note:—

The difficulty sometimes experienced in detecting the *Filaria sanguinis hominis*.

'I cannot avoid availing myself of the opportunity which this case also affords of reiterating the fact—for I feel that it cannot be done too strongly nor too often—that the detection of *Filariæ*, whether it be in the urine or in the blood, is sometimes a matter of very considerable difficulty. Hours may have to be spent in examining the sediment of apparently excellent samples of chylous urine before they are found; fresh supplies may even be required, for the numbers present may vary very much in different samples obtained from the same individual; and, as may be learnt from some of the cases narrated above, they may be even absent for a time from either the urine or the blood, or from both—at all events their detection required more patience than I was able to command at the time of examination, whereas they were obtained with tolerable ease from the same person on subsequent occasions: I have also observed that, occasionally, they will disappear altogether for some time previous to the disappearance of the chylous condition of the urine. It will therefore be evident that no great amount of foresight is required to be able to predict that, owing to want of proper appliances, want of time, or other circumstances, such remarks as "*Filariæ* were searched for, but not found," will, not infrequently, be recorded in connection with reports of chyluria cases.'

toms had not yet set in. When the disease commenced it was looked upon as a hydrocele, and the tumour was repeatedly tapped and a milky, pus-like fluid withdrawn. The swelling, however, continued to increase, became very painful, and eventually attained the size of a man's head. The patient was admitted into the Presidency General Hospital for "thickening and enlargement of the scrotum." The tumour was twice tapped in hospital, and the fluid removed sent to me for examination. It presented a somewhat purulent appearance, but the odour was not offensive. Under the microscope it was seen to consist of broken-down granular matter, and every slide of it contained some half-a-dozen specimens of the *filaria*.

With reference to the above it may be remarked that one of the patients suffering from chyluria which I described in the previous paper,* and whose blood was shown to be affected with hæmatozoa to an enormous extent, is now manifesting symptoms very like these, the scrotal affection having commenced some two years subsequent to those of chyluria. Filariæ may still be detected in his system.

The third occasion—Elephantoid condition of scrotum and foot, the latter becoming affected shortly after an attack of chyluria.

The third example of this class of the affection which I had specially observed was that of a middle-aged native, a patient of Dr. McConnell's at the Medical College Hospital. He was suffering from a second attack of chyluria, the first having come on a year pre-

* Eighth Annual Report of the Sanitary Commissioner, Appendix E, page 246.

viously and lasting some six weeks. He had an enlarged scrotum, which had lasted some seven years; but about six months after the advent of the chyluria his left foot and ankle began to enlarge, and now they present a well-marked elephantoid appearance—a condition which he referred to as "Goodah" in Bengalee.

About a dozen specimens of blood, obtained by pricking his fingers and toes, were subjected to microscopic examination, and each slide was found to contain two, three, or more specimens.

The fourth occasion—Elephantoid state of scrotum—History as to Chyluria not positively ascertained.

I will refer to one more instance showing the intimate connection existing between the presence of these hæmatozoa in the circulation and the elephantoid states above described. In May last Dr. Kenneth McLeod, Professor of Anatomy at the Medical College, very kindly forwarded for my examination about three ounces of a reddish-brown fluid, emitting a faint, but not disagreeable, odour, of slightly alkaline re-action, and with a specific gravity of 1·022. After standing awhile the reddish colouring matter partially subsided; the upper layer assumed a chyle-like aspect and formed an imperfect coagulum.

This fluid had exuded through minute orifices from soft tubercular elevations on the surface of the scrotum of a native patient. The scrotum is described as presenting a sponge-like aspect, especially on the left side, and as covered with yielding prominences from which fluid may constantly be squeezed—a condition which

appears to have existed about three years. On subjecting the sediment of this fluid to microscopic examination numerous living *filariæ* were readily detected.

Dr. McLeod has published an account of this case in a paper entitled "Remarks on Varix Lymphaticus or Nævoid Elephantiasis," * an essay which is particularly valuable, in that it not only gives a full and accurate description of this case, but in it the literature of the subject has also been carefully collected and analysed.

The views regarding the production of chyluria, &c., by local obstructions to the flow of fluid in the vessels.

With regard to the actual mode by which this leakage of nutritive fluid, whether chylous, sanguineous, or a mixture of the two, is produced, it is impossible in the present state of our knowledge to speak with certainty. Formerly, one of the best explanations of a mechanical nature that could be suggested was that of interruption to the flow of the nutritive fluid by the presence of tumours acting directly by pressure upon the lymphatics, or the smaller blood vessels, or indirectly by pressure on nerves, and thus interfering with the nervous supply of the part. The intermittent character, however, of the malady and its recurrence after long intervals of absence could not be explained in this way. One of the classes of the disorder, namely, that in which the sub-cutaneous tissues are affected, might possibly have been explicable by some such supposition as the lesions once produced—

* Indian Medical Gazette, August 1874.

the diseased action once established by interference with the nutrition of the part—might become permanent. The repeated recurrence of chyluria, however, at irregular intervals, would allow of no such simple explanation. And here I fear that Dr. Vandyke Carter's ingenious 'regurgitation' theory, as well as Dr. William Roberts' highly original theory of hypertrophy of the lymphatic tissue with subsequent acquisition of gland properties, would, in the ordinary run of the disease, as seen in a tropical climate, equally fail us. Nor would, indeed, the *exacerbations* which various elephantoid maladies frequently manifest be easily explicable on any such assumptions.*

Reasons for ascribing these morbid phenomena to a parasitic origin.

When, however, it is considered that tumours may be of parasitic origin, and that they may be in very intimate relation with the vascular system, enclosed in the same fibrous sheath, such as the tumours which may be frequently observed along the aorta in dogs (Plate I, Fig. 8), and which may well be conceived as exercising pressure upon the thoracic duct and important nerves, the difficulty of accounting for the erratic character

* It would be interesting to know whether the Hæmaturia of Egypt, Brazil &c., present similar, well marked exacerbations, especially as this disease is one well known to be associated with a parasite—the *Bilharzia hæmatobia* of Cobbold. Latterly, moreover, the Hæmaturia of Egypt has been found to be associated with the existence of a microscopic nematode in the blood, for Dr. Sonsino discovered two specimens in the blood of a young Egyptian Jew last February. In a communication just received from Dr. Sonsino he expresses his belief that the nematode which he found must be closely related to the *Filaria sanguinis hominis*. A highly interesting account of his observation has been communicated to the Academy of Naples. This fact relating to the Hæmaturia of Egypt is particularly interesting, when it is remembered that, some years ago, Dr. Wucherer discovered a microscopic nematode in the urine of a person suffering from the Hæmaturia of Brazil—although from the limited information we possess concerning these two parasites it would be quite premature to refer them to the same species.

of the disease is much simplified. Such obstructing causes as these need not be permanent, and probably are not so, but, as may readily be supposed, are very prone to recur in the same tissues, as such parasites manifest remarkable tendency to attack a particular organ and even particular parts of it. It is by no means improbable that the mature parasite having deposited its ova or embryos may shift its position and remain quiescent for a time in some out-of-the-way cellular tissue—sub-cutaneous or otherwise.

Probable mode of invasion of the mature *Filaria sanguinis hominis*.

It will be recollected that the entrance of the *Filaria sanguinolenta* into the blood vessels of the dog was shown to be effected by the migration of young immature worms (not exceeding $\frac{1}{12}$th of an inch in length) from the mucous surface of the œsophagus by perforation of its walls, and subsequently by penetrating the walls of the artery, thereby causing considerable disorganisation of the arterial tissue, and leaving more or less extensive aneurismal sacs as indications of the spots where the worm attained maturity. It is possible, and indeed highly probable, that a somewhat similar course is taken by the mature parasite of which the *Filaria sanguinis hominis* in the circulation is the offspring. It may be that it is not the œsophagus that is pierced and the thoracic aorta specially attacked, for this particular parasite may, perhaps, proceed as far as the duodenum, or still further down the alimentary canal, before it commences to follow its migratory instinct, and then find its way either directly into the aorta or reach the

circulation by some other channel, such as one of the mesenteric arteries. So that in this instance the tumours and lesions may be along the walls of the abdominal aorta or its renal and other branches, or even be situate in intimate relation to the *Receptaculum chyli* and the principal lymphatics. It is equally evident that the tissues along the urinary tract may be similarly attacked by the growing and matured parasites—indeed these structures may be specially liable to be invaded by them.

Possibility of the rupture of capillaries by embryo-filariæ.

Moreover, since it has been demonstrated that parasites, such as the *Filaria sanguinis hominis* can be detected in the capillary net-work of the blood-vessels, we have become aware of a factor capable of exercising no inconsiderable force compared with the resistance which the delicate walls of the capillaries of the vascular system generally are capable of withstanding; and when the extremely intimate relation which the capillaries hold to the lymphatic spaces, so carefully described by Dr. Klein,† and the excessive delicacy of the several partitions, are borne in mind, it is not to be wondered at that the urine under such circumstances should contain sanguineous and chylous fluid—the latter seldom or never without some trace of the former; and that extravasations of the same fluids should take place in the scrotum and elsewhere. Possibly these leakages occur far more frequently, and into more organs and tissues than at present imagined—the processes of assimilation, of absorption, and of re-

† The Anatomy of the Lymphatic System. 1—The Serous Membranes.

pair following the injury so quickly and so completely as not to attract special attention to the part.

Significance of the fact that escape of the nutritive fluids is not confined to the urinary tract.

The fact that these leakages are not limited to the urinary tract is of moment in considering the etiology and pathology of the disorder, inasmuch as it would have been difficult to imagine that rupture and extravasations could only occur in renal tissue or along the lining surfaces of the channels leading from it, for the capillaries have no such limited circulation; although, on the other hand, it might be argued that the urinary tract may have been affected by some such parasite specially localised in its own tissues just as the hepatic and pulmonary tissues have theirs; but the young at all events, of this *filaria* have a far wider distribution than this.

Pathological significance of the presence of mature worms in the heart.

Whether the mature worms—the parents of the microscopic nematode hæmatozoa in man—also take up their abode in the circulatory fluids, or merely deposit their ova (or embryos if viviparous) in such situations as will eventually lead to their being conveyed into the circulation, is of little moment, for the mischief which large-sized worms accomplish when merely lodged in the cavities of the heart and larger blood-vessels, judging from what we know of the *Filaria immitis* and other blood-worms, would seem not to be invariably or even generally of so serious a nature as might have been supposed. The injuries inflicted on the walls of the aorta of the dog by the *Filaria sanguinolenta*, described

on a previous page, are of a far more formidable character, and, in all probability, eventually interfere more with the well-being of the victim, than if the parasite had simply perforated the vessel and acquired maturity whilst, possibly, attached to one of the 'columnæ' of the heart.

Summary.

It is difficult to embody in a few words, without risk of misinterpretation, the substance of observations such as the foregoing on what is admitted to be an extremely difficult subject; nevertheless, it might be desired that I should express briefly (1), the chief reasons for the belief that chyluria and the elephantoid state of the tissues, referred to on a previous page, are associated with the presence of a microscopic hæmatozoon; and (2), in what manner, such connection being satisfactorily established, this fact can aid us in offering an explanation of the evidence we possess that the disease is due to mechanical interruption to the flow of the nutritive fluid in the capillaries and lymphatics:

(1).—With regard to the first clause, it may be sufficient to state that detailed histories of a considerable number of individuals affected in this manner have been published by me, and that in all the *Filaria sanguinis hominis* have been detected. I have now traced the *Filaria* to the blood *direct* in eleven, and detected them in one or other of the various tissues and secretions of the body in more than thirty individuals. The history of one of these persons could not be ascertained, but all the others were known to suffer,

or to have suffered, from Chyluria, Elephantiasis, or some such closely allied pathological condition.

(2).—With reference to the second clause our knowledge is not so exact, and almost all the inferences have to be drawn from observations made in connection with the hæmatozoon described in previous pages as occurring in pariah dogs. Judging from what may be seen in these, and from data which the only *post-mortem* examinations which I know to have been made of individuals affected with this parasite, I think that the interference with the flow of fluid in the lymphatic capillaries and smaller blood-vessels may not unreasonably be attributed to one or other of the following causes:—

a. To tumours, produced by encysted mature entozoa along the course of the blood-vessels and lymphatics, impeding the flow of fluid in them by pressure either directly, or indirectly by interfering with the functions of the nerves supplied to the part;

b. To the active migration of the immature, or rather partially matured parasite; the act of perforating the tissues—nervous or vascular—producing more or less permanent lesions;

c. To the activity of the liberated embryos in the capillaries causing the rupture of the delicate walls of these channels in which *possibly* ova may have accumulated owing to their size, or an aggregation of active

embryos taken place, either accidentally, or by the parent having migrated to the capillary termination of a blood-vessel and there given birth to a brood of microscopic blood-worms. Once the walls of the capillaries have given way the embryos pass into the adjacent lymph channels, the boundaries of which are so extremely delicate as practically to offer no impediment to the further progress of such active organisms. Should the lymphatic spaces be situated in intimate relation with a secreting surface, the escape of the minute *filariæ*, as well as the escape of fluid from the lymphatics with the ordinary secretion of the part, would seem to be a natural consequence.

At present I do not see that the facts at my disposal warrant any further deductions, but I trust that the description of the observations which have been made have been sufficiently clear that readers will be able to judge for themselves how prominent a part such a hæmatozoon may play in the causation of some of the diseases peculiar to tropical climates.

CALCUTTA,
1874.